FERMILAB
MAIN INJECTOR
MECHANICAL SUPPORT DEPARTMENT

NuMI Proton Extraction Kicker Magnet Cooling System Specification

SPECIFICATION #

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1. General

The cooling system described in this specification will be installed in the MI-60 service building for the NuMI project. Its purpose is to control the temperature of two Proton Extraction Kicker Magnet Load Assemblies. Fluorinert™ electronic heat transfer fluid is the cooling media used to remove the heat and reject it through a small plate type heat exchanger into the 45° F CHW chilled water system. This specification defines the requirements of a cooling system designed for high reliability and a long life with low maintenance and operation costs. The installation of these materials is detailed in the following drawings:

List of Drawings

Drawing Number	Title
8875.117-MD-363907	NuMI Proton Extraction Kicker Load Assembly Cooling P & ID
8875.117-ME-363909	NuMI MI-60 South to NuMI Kickers Fluorinert 1" Tubing Installation
8875.117-ME-363910	NuMI MI-60 South Utility Room Chilled Water Tubing Installation (work in progress)

2. Design Conditions and Pump Sizing Requirements

The following are the design conditions for the NuMI Proton Extraction Kicker Cooling System:

- Process Fluid: Fluorinert™ FC-77

  Process Fluid Temperatures:
  - 95º Fahrenheit Nominal Temperature (to be determined by experiment)
  - 60º Fahrenheit Minimum Temperature
  - 140º Fahrenheit Maximum Temperature

  Process Fluid Properties @95º F:

Density (lb/ft^3)	109.389
Viscosity (cP)	1.192
Specific Heat (BTU/lb-ºF)	.2508
Vapor Pressure (Psia)	.8137

- Total Heat Load: 1200 W
- 2 pumps piped in parallel (one in stand-by mode)
- 5 GPM each pump
- 7 Gallons total circulated Fluorinert™
- 100 ft. Total Dynamic Head
- Net positive suction head available ($NPSH_A$) is 10 feet (FC-77, SG 1.8)
- Net positive suction head required @ 60Hz ($NPSH_R$) is 4 feet (FC-77, SG 1.8)

3. System Construction

- **Pump and Motor Specifications**

The pumps for this project shall be sealless, leakproof, canned motor, regenerative turbine type. All wetted parts shall be of type 316 stainless steel and permanently marked with the material of construction. Stainless Steel parts shall be cast to the ASTM A744 standard (latest revision).

Fluorinert™ has very low surface tension and viscosity. This combined with the very low contact angles this fluid has on most surfaces, means that it will leak very easily through the smallest of passages. Seals that would easily hold back water at 10 atmospheres leak generously with a fluorochemical fluid. Magnetically coupled or canned pumps are much less apt to leak (source: 3M). A sealless canned motor pump was chosen for this system based on the following:

	Canned Motor	Mag-Drive
Advantages:	• Secondary containment of process fluid • Single shaft for impeller and motor • Only two carbon drive bushings required vs. four in mag-drive • Lower initial cost • Active hydraulic balancing system for shaft • Pump and motor are a single, sealless unit • Lower installation and operating costs • No alignment required • No external lubrication required • Liquid cooled motor	• Easily replaceable of-the-shelf motor • Simplicity of maintenance • Robust design
Disadvantages:	• Custom integral motor • Serviceability - maintenance seemingly more difficult	• Potential leak path if containment can compromised • Separate bearings/shaft for impeller and motor • Alignment required between pump and motor • Higher initial cost (high-tech coupling magnets) • Potential for de-coupling magnets

The following are the sizing requirements for the pump:

- It is desirable that the operating point for the system be at or to the left of the "best efficiency point of the pump."
- Pump shall have ample run-out on its curve to avoid both cavitation and exceeding the motor’s service factor
- 3 phase, 230 volt, 60 Hz
- Motor is suitable for use with a variable speed drive

The following chart was used to evaluate VFD drive vs. Bypass Loop:

	Variable Frequency Drive	Bypass Loop
Advantages:	• “Infinite” adjustability allows better matching of system curve • Better control of system pressure • No pressure regulator required • Higher efficiency possible	• Low cost • Simple and reliable
Disadvantages:	• Additional complexity and reliability concerns (planned redundancy minimizes this) • Additional cost	• Lost efficiency • Requires pressure regulator • Adds to heat load • Limited adjustability

Below is the pump curve for the Crane Dynapump:

- **Heat Exchanger**

The heat exchanger is a Tranter Maxchanger all-welded plate type to eliminate any chance of the cooling fluids intermingling and is constructed of 316 stainless steel for corrosion resistance. It is sized to remove 1200 W of heat from 5 GPM of Fluorinert™ FC-77 with 2 GPM of 45°F Chilled Water (CHW). It is rated for full vacuum and will be leak checked here before being put into service.

- **Process Control**

The controller chosen for this system is a Powers 535. It has a proven its reliability all over the Main Injector and is well known to the technicians and engineers that work on the water systems. It will operate the control valve based on the temperature signal it receives from an RTD downstream of the heat exchanger. This sensor location was chosen to provide quicker response, better accessibility, and greater control valve stability. It was debated whether this sensor should be down in the tunnel near the kickers but at an average velocity of 2.5 ft/sec, it will take over a minute for the fluid to travel from the heat exchanger to the device. The lines will be thermally insulated with a ½" thick elastomeric material to minimize heat transfer.

- **Control Valve**

The control valve was chosen for its known reliability (there are more than a dozen in operation in LINAC) and its adjustability if system parameters change (there are 13 trim sizes available for this valve). It is a Kammer® Low Flow, Series 030000, and model 30057. It is an electrically actuated ½" globe valve with an integral electronic positioner, and is fabricated of 316 S.S. The valve flow coefficient (C_v) chosen is 1.2 so it operates in the 50-80% valve travel range while modulating the flow of CHW through the heat exchanger as determined by the P.I.D. controller to maintain the desired setpoint.

- **Expansion Tank**

The decision to size the expansion tank at 5 gallons was based on several factors. Firstly, during operation the level will be maintained at 2.5 gallons to provide a safety margin against minor fluid losses. Secondly, to increase the system volume to 7 gallons effectively diluting any byproducts of radiation induced decomposition. Thirdly, to add to the temperature stability of the system by increasing the thermal mass. The expansion tank or fluid reservoir will be a custom fabrication of 316L S.S. for corrosion resistance, incorporate a corrosion allowance of .035" to the wall thickness, and include the following ports:

On Top

- 2" FNPT - Level Indicator
- 2" FNPT - Level Switch/Temperature Sensor
- 1" O.D. .083" wall 316L Tubing - Inlet
- 1" Tubing - Pressure Safety Valve/Pressure Indicator
- ¼" FNPT - Nitrogen Pressure/Vent

On Bottom

- 1" O.D. .083" wall 316L Tubing - Outlet
- ½" O.D. .049" wall 316L Tubing – Drain

The tubing inlet and outlet connections are intended to eliminate leaks in the flow path through the use of compression fittings.

- **Materials**

All Fluorinert lines shall be composed of 1", ¾", and ½" type 316/316L Stainless Steel tubing with smooth bends and a minimum of drag inducing geometry. The tubing will be of sufficient quality to provide a gas tight seal with double ferrule type compression fittings. All chilled water lines shall be constructed of 1" 304L S.S. schedule 10S pipe. Tubing was chosen for the Fluorinert to minimize pressure drop and to avoid the use of threaded joints.

- **Welding Specification**

All welding shall be performed in accordance with ANSI/ASME B31.3 Process Piping Code as described in Fermi Specification #1504-ES-444002. The NuMI Proton

Extraction Kicker Cooling System shall be considered as “Normal Fluid Service” when interpreting Code requirements.

- **Overflow Tank**

A 316 S.S. Pressure Safety Valve set at 50 psi will be installed in the main supply line at Q602 to protect the Kicker Load Assemblies from over-pressurization. The Pressure Safety Valve discharge shall be connected to a seven gallon ASME-Code type epoxy-lined steel tank. This tank will be mounted in an out of the way place on the inside wall of the tunnel.

- **Fluid Connections**

The entire Fluorinert™ system will be welded or use Swageloc® or A-LOK® double-ferrule type compression fittings where possible per 3M’s recommendations. Any threaded joints will use LeakLock™ thread sealant. The chilled water (CHW) system sealing requirements are less stringent. The system will be predominantly welded schedule 10S pipe or use threaded fittings with Loctite® 569 thread sealant.

- **Valves**

The system requires many ball valves to isolate individual components for maintenance or replacement. 3M recommends using Swageloc® or A-LOK® double-ferrule type compression fittings which adds considerable cost to the valve. As Fluorinert itself costs $400 a gallon minor leaks could be major dollars. There are o-ring compounds that Parker recommends for sealing Fluorinert but these elastomers aren’t offered as the seat material for small ball valves. The best candidate is ultra-high molecular weight polyethylene (UHMWE) because it has proven radiation resistance. This summer during testing of the prototype load assembly we will test valve/seat/seal combinations to determine their relative ability to seal Fluorinert.

- **Instrumentation**

There shall be instruments measuring the Fluorinert:

- Flowrate leaving the pump
- Pump suction line pressure
- Pump discharge line pressure
- Expansion tank level
- Pressure entering the loads
- Pressure exiting the loads
- Temperature entering the loads
- Temperature exiting the loads
- Pressure drop across the alumina filter
- Pressure drop across the particulate filter
- Pressure drop across the filter/dryer

There shall be instruments measuring the Chilled Water (CHW):

- Temperature entering the heat exchanger
- Temperature exiting the heat exchanger
- Flowrate entering the heat exchanger

- Pressure drop across the heat exchanger

- **Interlocks/Safety**

The system must "fail safely" and shut itself down if necessary based on the following parameters:

- Level high
- Level low
- Temperature high
- Pressure high
- Flow low

- **Alarms**

The system must send a signal to ACNET warning that a process variable is approaching an unacceptable condition. Alarms will be sent for the following:

- Temperature
- Pressure
- Flow

- **Heater (future option)**

It shall be a low temperature type (<10 watts/in^2 &160°F maximum temperature) to prevent boiling the FC-77 and capable of heating the fluid to the desired operating temperature within 3 minutes or less. It would be operated by the P.I.D. controller.

4. Performance Tests Requirements

The heat exchanger supplied shall be leak tested prior to shipping. A serial numbered characteristic curve and a tabular data sheet shall accompany the pumps upon delivery. Data shall include:

- A Measured Pump Curve showing Flow (gpm) verses Head (ft) at 30, 40, 50, and 60 Hz.
- A Measured Pump Curve showing NPSHR verses flow
- A drawing showing the location of the inlet and outlet piping connections
- A drawing showing the overall dimensions and the gross weight of the assembly